GAO

May 1996

WEATHER FORECASTING

Recommendations to Address New Weather Processing System Development Risks

GAO/AIMD-96-74

GAO

The Honorable Mickey Kantor
The Secretary of Commerce

Dear Mr. Secretary:

On February 29, 1996, we testified on the National Weather Service's (NWS) Advanced Weather Interactive Processing System (AWIPS)—the cornerstone of NWS' $4.5 billion modernization program—before the Subcommittee on Energy and Environment, House Committee on Science.[1] This report officially transmits recommendations we made as part of our testimony which, if implemented, will strengthen NWS' ability to achieve a fair return on its AWIPS investment.

First, as we also recommended in our February 1996 report[2] on AWIPS, NWS should (1) expand ongoing AWIPS requirements review activities to include validation that proposed capabilities are justified on the basis of mission impact and (2) implement only those capabilities that are validated. These recommendations are grounded in NWS' long-standing assertion that the modernization and its component systems will produce significant public service improvements—namely, better forecasts at reduced costs. To achieve these goals, NWS has specified that AWIPS must provide about 450 high-order capabilities, such as the ability to execute certain models or display data in certain formats and colors. These high-order capabilities are composed of about 22,000 individual system requirements.

We testified that while NWS has done a commendable job of incorporating the views of the forecasting community in defining AWIPS' capabilities, it has not demonstrated that all proposed capabilities will produce expected mission impacts. We have found that successful public and private organizations tie decisions on information technology investments to explicit and quantifiable mission improvements.[3] By failing to do the same, NWS risks building either more or less into AWIPS than necessary, which, either way, translates into lowering AWIPS' return-on-investment.

---

[1]Weather Forecasting: New Processing System Faces Uncertainties and Risks (GAO/T-AIMD-96-47, February 29, 1996).

[2]Weather Forecasting: NWS Has Not Demonstrated That New Processing System Will Improve Mission Effectiveness (GAO/AIMD-96-29, February 29, 1996).

[3]Executive Guide: Improving Mission Performance Through Strategic Information Management and Technology (GAO/AIMD-94-115, May 1994).

Second, we testified that NWS has wisely chosen to break AWIPS software development into increments, which is a widely accepted means of reducing software development risks. However, we believe that NWS' approach to implementing this strategy makes AWIPS development unnecessarily risky because NWS chose to overlap development of these builds, beginning development of a new build before the prior build is fully stabilized. In doing so, it increased the chances of potential defects being passed along module-to-module. Accordingly, we recommended that NWS ensure that each build is fully tested and all material defects are corrected before software development associated with the next build begins.

Third, we recommended in our testimony that NWS establish a software quality assurance program to increase the probability of delivering promised AWIPS capability on time and within budget. While NWS has reported a number of software development process improvements, including preparing a software development plan, we believe its failure to establish a software quality assurance program to monitor NWS' in-house development processes and products unnecessarily puts AWIPS' current cost, schedule, and performance goals in jeopardy. Such a program would provide independent assurance that software development processes and products meet prescribed standards and that any identified deficiencies in process or product are brought to management's attention sooner rather than later, thus minimizing costly system rework. Employing a software quality assurance program is a common practice among public and private organizations with solid reputations for producing quality software.

Finally, in our testimony, we recommended that NWS obtain an independent assessment of the cost to develop and deploy AWIPS. We testified that NWS currently does not have reliable cost information on AWIPS development and deployment costs and that its current estimate of $525 million, which has not changed for more than 1 year, omits certain costs and is thus understated. For example:

- The $525 million estimate includes neither known deployment phase contract cost increases nor NWS internal program management costs resulting from NWS' 1995 decision to extend AWIPS deployment 1 year. In our discussions with NWS officials, contract costs associated with the extension were estimated to be about $9 million, while NWS program management costs for the additional year had yet to be estimated.
- The estimate omits a known cost increase in the development phase contract of about $10 million. While NWS officials stated that this increase

will be offset by reductions in the deployment phase contract, the terms of the deployment phase have yet to be renegotiated.

- The estimate omits the cost of AWIPS product improvements that were recently identified and are planned for 1999. These improvements are estimated to cost about $2 million.
- The $525 million estimate, when originally derived, included about $49 million for future development and deployment phase contract modifications—a $34 million decrease from the amount NWS included in its 1992 project cost estimate. Since 1994, however, NWS officials told us that more than $42 million of the $49 million in reserve has been allocated to known contract costs, leaving relatively meager reserves for inevitable modifications. Omitting adequate reserves at this stage in AWIPS' development cycle is inconsistent with prudent software engineering practices. According to software engineering experts, the size of a system's software at this stage in its development life cycle could grow by as much as 50 percent.

As we testified, NWS has an opportunity with AWIPS to substantially improve its weather forecasting capability. If the recommendations we made in our testimony and in this report are implemented, NWS can position itself to take full advantage of this opportunity.

Agency Comments and Our Evaluation

In its written comments on a draft of this report, the National Oceanic and Atmospheric Administration (NOAA) generally disagreed with our conclusions and recommendations. A summary of NOAA's specific comments and our evaluation of them follows. We have incorporated other NOAA comments in the report where appropriate.

NOAA disagreed with our first recommendation to (1) expand ongoing AWIPS validation activities to include justifying proposed capabilities on the basis of mission impact and (2) implement only mission-justified capabilities. According to NOAA, completed and ongoing requirements reviews and risk reduction activities as well as operational test and evaluation of each AWIPS release are sufficient to ensure that unneeded AWIPS capabilities are revised or not implemented. In addition, NOAA added its view that validating capabilities to mission impact is not efficient or cost-effective and would cause further delay and expense to the program. We disagree. While we reiterate our commendation for AWIPS requirements reviews and risk reduction activities to date and support plans to prototype future system releases, the fact remains that none of these activities were or are intended to demonstrate the mission impact of AWIPS capabilities.

Moreover, waiting until the operational test and evaluation stage of each AWIPS release is too late to assess mission impact because by this time considerable sums of money will have already been invested in the capabilities' development. Additionally, while validating capabilities to mission impact would require some resource investment now, it could also prevent time and money being spent unnecessarily on developing AWIPS capabilities that promise little in terms of mission improvement. Thus, we continue to support our recommendation.

NOAA did not comment specifically on our second recommendation to fully test and correct all material defects in each AWIPS build before software development associated with a succeeding build begins. However, NOAA stated that its plans for overlapping AWIPS' builds does not introduce unnecessary risks and stated that judicious overlapping is efficient and appropriate for those builds that do not need to wait for the previous build to be "frozen." Further, while acknowledging the potential risks of AWIPS build overlaps, it noted two factors that mitigate these risks. First, NOAA stated that there is minimal overlap associated with builds 1 and 2 and that the two areas in which overlap occurs (data modeling and communications software) are inherently stable because of early development and demonstration activities. Second, NOAA stated that development in the later builds is primarily hydrometeorological applications and that these applications will not interact directly with each other. We agree that overlapping builds can be appropriate and efficient, and that "freezing" one build before moving to the next is not always efficient. Further, we are not questioning the degree of interaction among hydrometeorological applications. Our concern is that AWIPS plans call for extending or adding to baseline applications, such as those that process radar or satellite products for display on AWIPS monitors, in succeeding builds before these baselines have even begun formal testing—much less before the build has been stabilized—by removing all material defects. By not doing so, NWS runs the risk of introducing defects on top of unresolved defects. Thus, we continue to support our recommendation that NWS fully test each AWIPS build and correct all material defects before beginning software development associated with the next build.

Although NOAA did not directly address our third recommendation to establish an AWIPS quality assurance program, it agreed that software quality assurance is important for NWS in-house software development (i.e., hydrometeorological applications), and it stated that NWS has hired a computer specialist for the AWIPS program manager's staff to oversee the government's software development activities. NOAA also stated that NWS is

following accepted software development practices and that an independent review team draft report gives a "generally favorable impression of the current development methodology." Despite NWS' recent actions, it is important to implement our recommendation for two reasons. First, hiring a computer specialist falls far short of our recommendation because such action does not provide either the structure or content of a disciplined, thorough, or independent quality assurance program. Second, since NOAA provides no evidence or details of actions taken to follow "accepted software development practices" and no basis for the "generally favorable impression" of its development methodology, these points are unconvincing. Thus, we continue to support our recommendation.

Finally, NOAA disagreed with our fourth recommendation to obtain an independent assessment of the cost to develop and deploy AWIPS, adding that it plans to reevaluate its current cost estimate of $525 million in August 1996 when the deployment phase contract is renegotiated and that it anticipates no significant increases in the current estimate. NOAA further stated that developing a new estimate at this time would add little value to program and budget planning. In defending the validity of its current estimate of $525 million, NOAA also dismissed each of the omitted cost items cited in our report for reasons cited below. We disagree that a new estimate would add little value, particularly in light of expressed interest by members and staff of the Subcommittee on Energy and Environment, House Committee on Science, in having an up-to-date, reliable estimate upon which to base authorization decisions. Because NOAA did not acknowledge that these costs should be included in their project cost estimate, we believe our recommendation remains valid. NOAA's comments on each of the omitted cost items cited in our report and our response follow.

- NOAA stated that the $9 million increase associated with extending the deployment phase by 1 year should not be added to the AWIPS project cost estimate because NWS is committed to completing the deployment phase in 24 months as originally planned. This contradicts NWS documentation dated February 9, 1996, stating that the AWIPS deployment phase would be extended 1 year and would result in an additional $9 million, and NOAA has provided no documentation rescinding this plan or reassessing its cost.
- NOAA repeats its claim that the omission of a $10 million cost increase to the development phase contract will be offset by a corresponding decrease in the deployment phase contract. However, as stated in our report, since the deployment phase contract has yet to be renegotiated, there is no basis for NOAA's claim.

- NOAA stated that the $2 million omission for recently identified product improvements should not be included in the AWIPS cost estimate because this AWIPS enhancement will be developed after the deployment phase is completed. We disagree. Known system development costs cannot rationally be excluded from cost estimates. Moreover, the AWIPS project cost estimate already includes numerous other AWIPS product improvements and thus excluding the cost of this product improvement would be inconsistent with NWS' own practice.
- NOAA acknowledged that the $525 million estimate provides a relatively small reserve for contract modifications needed to address such things as code growth. However, NOAA contends that inherent conservatism in the deployment phase component of the estimate will ultimately produce more contingency money than is currently apparent in the estimate. Also, NOAA stated that it does not expect major modifications for the remainder of the development phase. Despite NOAA's optimism, it admits that contract costs (development and deployment) are the greatest variable in the current cost estimate. Further, prudent software engineering practices recommend planning for as much as 50 percent growth in software size for systems at AWIPS' stage of development. Finally, federal agencies' past performance in acquiring major, software intensive systems is routinely characterized by high cost overruns and significant schedule slippage. Thus, we find no basis for NOAA to conclude that contingency money will appear before the deployment phase contract is renegotiated.

The full text of NOAA's comments is provided in appendix I.

This report contains recommendations to you. The head of a federal agency is required by 31 U.S.C. 720 to submit a written statement on actions taken on these recommendations to the Senate Committee on Governmental Affairs and the House Committee on Government Reform and Oversight not later than 60 days after the date of this report. A written statement also must be sent to the House and Senate Committees on Appropriations with the agency's first request for appropriations made more than 60 days after the date of this report.

We are sending copies of this letter to each member of the Subcommittee on Energy and Environment, House Committee on Science, and other interested parties. We will send copies to others upon request. If you have questions or wish to discuss the issues in this report further, please contact me at (202) 512-6240. Major contributors to this report are listed in appendix II.

Sincerely yours,

Jack L. Brock, Jr.
Director, Information Resources Management/
    Resources, Community, and Economic Development

Contents

Abbreviations

AWIPS	Advanced Weather Interactive Processing System
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service

Comments From the National Oceanic and Atmospheric Administration

UNITED STATES DEPARTMENT OF COMMERCE
The Under Secretary for
Oceans and Atmosphere
Washington, D.C. 20230

April 17, 1996

Mr. Gene L. Dodaro
Assistant Comptroller General
Accounting and Information Management
   Division
United States General Accounting Office
Washington, D.C. 20548

Dear Mr. Dodaro:

Enclosed is the Department of Commerce's reply to the General Accounting Office draft report: Weather Forecasting: Recommendations to Address New Weather Processing System Development Risks (GAO/AIMD-96-74).

These comments were prepared in accordance with the Office of Management Budget Circular A-50.

Sincerely,

D. James Baker

Enclosure

THE ADMINISTRATOR

The National Oceanic and Atmospheric Administration's (NOAA)
Response to the General Accounting Office (GAO) Draft Report:
"Weather Forecasting: Recommendations to Address New Weather
Processing System Development Risks (GAO/AIMD-96-74)," dated
April 1996.

Recommendation 1: *First, as we recommended in our February 1996
report on the Advanced Weather Information Processing System
(AWIPS), the National Weather Service (NWS) should (1) expand
ongoing AWIPS requirements review activities to include
validation that proposed capabilities are justified on the basis
of mission impact and (2) implement only those capabilities that
are validated."*

See comment 1.

NOAA prepared a formal response to these recommendations
made in the GAO February 1996 report on AWIPS. We do not
agree with them. The best, and often only, method for
validating the proposed capabilities is to continue with
planned risk reduction activities and the operational test
and evaluation of each system release. Both these
activities will provide vital information back into the
development process so we can be assured that the system
capabilities are validated. This process will ensure that
capabilities that are not needed will be revised or not
implemented.

Expending the additional time and resources required to
validate all capabilities on the basis of mission impact
in advance of incremental deployment is not an efficient
or cost-effective process. If implemented, the recommended
actions would cause further delay and expense to the
program and yield no significant reduction in program
risk. The current risk that resources will be devoted to
developing, testing and deploying unnecessary capabilities
is negligible. The risk that the NWS will not be able to
maintain operations with archaic systems without AWIPS is
high. The inability of NWS to capitalize on powerful new
information services already available from the
modernization without AWIPS is certain. We are confident
that the requirements reviews and risk reduction activities
mentioned in the GAO report and ongoing risk reduction and
operational test and evaluation activities are sufficient to
validate AWIPS capabilities.

Recommendation 2: *"Accordingly, we recommended that the NWS
ensure that each build is fully tested and all material defects
are corrected before software development associated with the
next build begins."*

See comment 1.

NOAA does not agree that the overlapping build approach
employed for AWIPS development introduces unnecessary risk.
As identified in the GAO report, incremental development is
a common approach used throughout the software industry for
reducing development risks. Throughout the AWIPS

development life-cycle we propose to follow this
risk -reducing approach. GAO does not take exception to
the proposed incremental nature of AWIPS development, but
only to the proposed overlap of AWIPS' software builds.
There are two aspects of the incremental approach being
incorporated into the AWIPS development which mitigate these
potential risks.

First, much of the basic system infrastructure is being
developed in the early builds (1 and 2), during which
overlap is not being generally applied. The only overlaps
of activity between Builds 1 and 2 are in the areas of data
modeling and enhancements to some communications software.
Build 2 data modeling provides information to fill in
build-specific details based on a stable overall AWIPS
conceptual data model, developed during the summer and fall
of 1995 during an extended set of sessions between PRC data
modelers and government data experts. This build-specific
data modeling activity is an analysis step which must be
completed before any software upgrades to data management
modules can be made to meet requirements for data access by
Build 2 applications through Build 2 data objects.

The communications software components for Build 1 are,
to a significant degree, taken from the long-lead-time
satellite broadcast network software components implemented
and tested operationally during the Pathfinder development
and deployment. Thus, stable functionality of the Build 1
communications software has already been demonstrated
operationally. This stability has allowed the
communications developers to move into Build 2 detailed
design and development activities prior to the formal
acceptance of Build 1.

Second, much of the development in later builds will be
in hydrometeorological (HM) modules which use the system
infrastructure. Many HM applications will be "display
oriented" and will not interact directly with each other.
The main coupling among the HM applications is through
the organization of data in the AWIPS database. As with
Build 2, an early data modeling activity will benefit every
AWIPS build so that the data needed to test applications
would be available in a timely fashion and would allow for
smooth integration of HM applications within any given
build's development cycle.

Because of the way AWIPS functionality is evolving
throughout the program life-cycle, an incremental, low-risk
approach that allows judicious overlapping is efficient and
appropriate for those build components that do not need to

wait for the previous build configuration to be frozen. In
the case of data modeling, it is a necessary first step to
any build's development and must be started early to avoid
costly delays in delivery of the incremental AWIPS
capabilities that will be growing with each build.

Recommendation 3: *"Third, we recommended in our testimony that
NWS establish a software quality assurance program to increase
the probability of delivering promised AWIPS capability on time
and within budget."*

See comment 1.

NOAA agrees that software quality assurance is important for
the hydrometeorological applications. A computer specialist
has been hired for the AWIPS Program Manager's staff to
oversee software development activities, including
government developed software, from a program standpoint.
Quality assurance is one of the responsibilities of this
position.

Accepted practices of software development are being used in
the development of hydrometeorological applications. Peer
reviews and code walkthroughs are standard. Formal testing
is conducted by an independent designated tester and
regression tests are performed as necessary. Testing will
be performed on the NWS Headquarters Test and Integration
Facility, an AWIPS system, which is kept under project
configuration control. Trouble reports are generated and
tracked.

An independent review team recently studied the Government's
software development process at the request of the
Department of Commerce. In their draft report, the team
gave a "generally favorable impression of the current
development methodology." Their primary concerns in the
area of software development related to development at a
local level and how the methodology for doing this would be
established.

Recommendation 4: *"Finally, in our testimony, we recommended that
NWS obtain an independent assessment of the cost to develop and
deploy AWIPS."*

See comment 1.

NOAA does not agree that an independent assessment of costs
for the development and deployment of AWIPS should be
conducted. The current estimate at completion (EAC) for the
development and deployment of AWIPS is $525 million. This
estimate was developed in December 1994 on the basis of
Government estimates of contract costs for both the
Development and Deployment Phases in the restructured

program. Since then, the Development Phase of the contract
has been renegotiated and NOAA will enter into negotiations
later this month on the contract modification for the
Deployment Phase. We recently completed an independent
Government cost estimate for the Deployment Phase, and in
that context, reviewed the total Development and Deployment
Phase costs contained in the EAC. We do not anticipate a
significant increase overall for these two phases. By
August 1996, we will have negotiated costs for both phases
and will reevaluate the EAC at that time. Since contract
costs are the greatest variable in the EAC, developing a new
estimate at this time would add little value to program and
budget planning.

The GAO report states that there was a decision to extend
AWIPS deployment for one year. NOAA is proceeding with a
24 month deployment schedule, as planned. The additional
1-year window is included in the request for proposal to PRC
regarding the modification to the Deployment Phase. This
contract structure is being considered to provide
contractual flexibility in the event of funding shortfalls
in FY 1997 and FY 1998. PRC has been asked to price this
modification based upon a deployment schedule that is
completed 30-months after the start of the Deployment Phase.
The $9 million increase quoted by GAO is based on this
30-month schedule. NOAA is committed to completing the
deployment in 24 months and has focused all planning,
scheduling, and resources of the AWIPS program to meet this
goal. The EAC will not be revised to accommodate the
30-month schedule unless, and until, NOAA revises its plan.

The GAO report references $10 million in Development Phase
costs which were not accounted for in the 1994 EAC. These
are costs which were originally included in the Deployment
Phase estimate. They will be paid either in the Development
Phase or the Deployment Phase, but not in both. Therefore,
this increase in the Development Phase costs will result in
a corresponding decrease in the deployment phase costs.

The GAO report states that $2 million for product
improvement is not included in the EAC. The AWIPS program
is planning for future product improvements after the
completion of the Deployment Phase. The resources planned
for this effort should not be included in the EAC for the
program, as the EAC represents costs only through the end of
nationwide deployment. The resources for this effort
represent life cycle costs of AWIPS, similar to operations
and maintenance costs.

See comment 2.

The GAO report states that the EAC does not include
additional costs associated with the Government's
responsibility for developing all hydrometeorological
applications. This is not correct. When the $525 million
estimate was established in 1994, the design of the
restructured program was known, including Government
responsibility for hydrometeorological applications. This
responsibility was accounted for in the 1994 EAC and is
included in the $108 million estimate for Government
Activities.

The GAO report raises concerns that the program does not
have adequate reserves. Although the amount of reserve
available for contract modifications is relatively small, we
believe that our deployment phase estimates are conservative
and that there will be more contingency in the EAC than is
now apparent. Furthermore, since the restructured
Development Phase contract incorporates most of the
additional requirements envisioned by the program, we do not
anticipate major modifications for the remainder of the
Development Phase.

The following are GAO's comments on the National Oceanic and
Atmospheric Administration's letter dated April 17, 1996.

GAO Comments

1. Discussed in the "Agency Comments and Our Evaluation" section of the
report.

2. Discussion of this point deleted.

Major Contributors to This Report

Accounting and Information Management Division, Washington, D.C.

Rona B. Stillman, Chief Scientist for Computers and Telecommunications
Randolph C. Hite, Assistant Director
Keith A. Rhodes, Technical Assistant Director
David A. Powner, Evaluator-in-Charge
Robert C. Reining, Information Systems Analyst
Colleen M. Phillips, Information Systems Analyst
Cristina T. Chaplain, Communications Analyst

Ordering Information

The first copy of each GAO report and testimony is free.
Additional copies are $2 each. Orders should be sent to the
following address, accompanied by a check or money order
made out to the Superintendent of Documents, when
necessary. VISA and MasterCard credit cards are accepted, also.
Orders for 100 or more copies to be mailed to a single address
are discounted 25 percent.

Orders by mail:

U.S. General Accounting Office
P.O. Box 6015
Gaithersburg, MD 20884-6015

or visit:

Room 1100
700 4th St. NW (corner of 4th and G Sts. NW)
U.S. General Accounting Office
Washington, DC

Orders may also be placed by calling (202) 512-6000
or by using fax number (301) 258-4066, or TDD (301) 413-0006.

Each day, GAO issues a list of newly available reports and
testimony. To receive facsimile copies of the daily list or any
list from the past 30 days, please call (202) 512-6000 using a
touchtone phone. A recorded menu will provide information on
how to obtain these lists.

For information on how to access GAO reports on the INTERNET,
send an e-mail message with "info" in the body to:

info@www.gao.gov